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The goal of this contract (N00014-07-C-0722) is to develop a portable system for underwater port security focusing on ship hull scanning. This, and previous efforts, have been to develop a system that meets the requirements of the Coast Guard, the Navy Explosive Ordnance Disposal Team (EOD) and local law enforcement. The result is a Mobile Inspection Package (MIP), capable of surveying ship hulls, seawall, pilings, and seafloors. The MIP can be mounted on numerous platforms such as a Coast guard vessel, a Remotely Operated Vehicle (ROV), or an Autonomous Underwater Vehicle (AUV). Previous versions of the MIP have been extensively validated in real-world conditions, and under operational constraints, in collaboration with the US Coast Guard (e.g., Super Bowl XXXIX with the Coast Guard and the Jacksonville Sheriff's Office).

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Unclassified	Unclassified	Unclassified		9	John Kloske

19b. TELEPHONE NUMBER *(Include area code)*: (727) 553-1099

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3 November 2008

Dr. Thomas Swean, Jr.
Office of Naval Research
Office of Naval Research
ONR Code 321
875 North Randolph Street
Arlington, VA 22203-1995

Subject: Annual Report

Reference: Contract N00014-07-C-0722
(SRI Project P18063)

Dear Dr. Swean:

SRI International is pleased to submit our Annual Report entitled "Testing and Evaluation of the Mobile Inspection Package." This report has been prepared in accordance with the requirements of CDRL A001 of the referenced contract.

Technical questions concerning this report should be addressed to John Kloske at (727) 553-1099; all other matters should be addressed to me at (650) 859-4424.

Sincerely,

Margaret Baxter-Pearson

Margaret Baxter-Pearson
Division Manager of Contracts

Enclosure

Cc: DCMA Northern California – Letter Only

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SRI International

Final Report • October 2008

TESTING AND EVALUATION OF THE MOBILE INSPECTION PACKAGE

Final Report

ESD-18063-FR-08-277
SRI Project No. P18063
Contract No. N00014-07-C-0722

Prepared by

John Kloske, Program Manager
Engineering & Systems Division

Prepared for

Office of Naval Research
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Suite 425
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Attention: Dr. Tom Swean

1 INTRODUCTION

The goal of this contract (N00014-07-C-0722) is to develop a portable system for underwater port security focusing on ship hull scanning. This, and previous efforts, have been to develop a system that meets the requirements of the Coast Guard, the Navy Explosive Ordnance Disposal Team (EOD) and local law enforcement. The result is a Mobile Inspection Package (MIP), capable of surveying ship hulls, seawall, pilings, and seafloors. The MIP can be mounted on numerous platforms such as a Coast guard vessel, a Remotely Operated Vehicle (ROV), or an Autonomous Underwater Vehicle (AUV) (Figure 1). Previous versions of the MIP have been extensively validated in real-world conditions, and under operational constraints, in collaboration with the US Coast Guard (e.g., Super Bowl XXXIX with the Coast Guard and the Jacksonville Sheriff's Office).

An issue yet to be addressed is the scanning of a vessel's hull; specifically, before it enters the port (the focus of this contract). The ability to scan a "target" vessel before it has entered the port has several benefits: primarily the ability to detect a threat while it is far away from creating a hazardous situation and providing law enforcement an appropriate amount of reaction time. An AUV would be an ideal platform to support the MIP during this kind of operation. SRI's plan is to enhance the Mobile Inspection Package AUV payload to include a wide field of view 3DSLS "line sonar". Follow-on activities include the testing and evaluation of the MIP-equipped BF12 AUV for ship hull scanning.

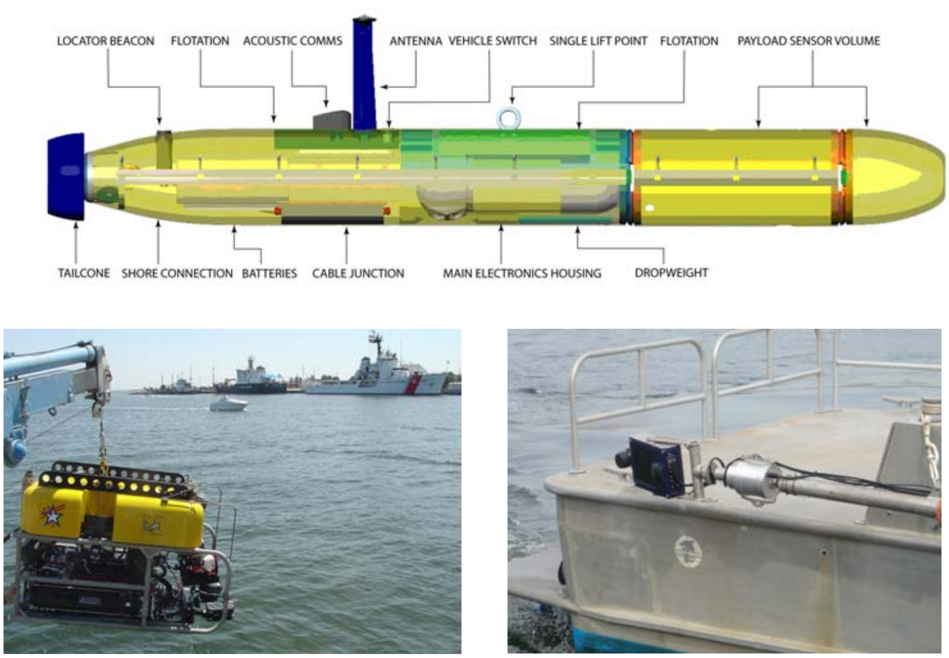

Figure 1. MIP platforms.

2 APPROACH

The MIP's latest design includes both a 3D sonar for target detection (and verification of coverage area) and a high resolution 2D imaging sonar for target identification. Because the scanning of ship hulls offshore will affect the ship's schedule, the AUV scanning method must minimize the time required for this task and provide verification that the hull was completely scanned. Scanning includes geometrically complex regions such as the stern section, where the large amount of vertical relief and numerous open spaces; the use of mosaiced 2D sonar images for this application is impractical. To scan these geometrically complex regions, while minimizing scan time, requires use of the largest–swath-width 3D sensor. However is important to also consider appropriate data resolution for minimum-sized target detection.

The current 3D sonar used in the MIP is the BlueView 1.35 MHz 3DSLS. The horizontal field of view (FOV) of the 3DSLS is 45 degrees. We sought to work with BlueView to increase the 3DSLS' horizontal FOV to 90 degrees and to improve the signal-to-noise ratio (SNR) of the acoustic returns. This would double the swath width and reduce the overall ship scanning time. SRI installed the 90 degree FOV 3DSLS as part of the MIP AUV payload and tested the MIP using the BF12 tail section for both sea floor bottom scans as a baseline and on the bottom of ship hulls, both in Tampa Bay and offshore.

The goal was to develop offshore ship hull scanning techniques with an AUV-based MIP. Initially, testing was performed with the AUV in coastal waters to establish the AUV's characteristics with this new suite of sensors. Once the AUV had been thoroughly tested, controlled under-hull scans were done in coastal waters. This helped to establish and refine operational techniques to maximize efficiency, data collection, and safety. This effort also allowed for the future investigation of the development of a high resolution wide field of view 3DSLS operating at 2.7 MHz, which has the potential to approach the data resolution of the MIP 3D Laser Line Scanner (Figure 2).

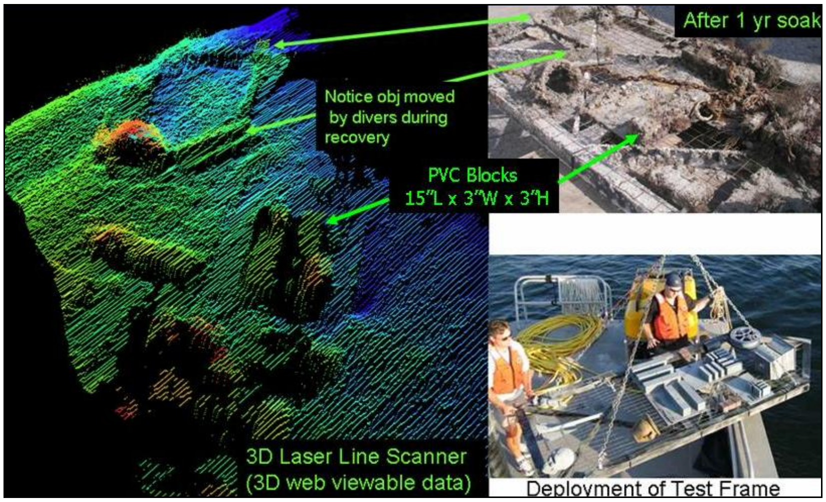

Figure 2. MIP Laser Line Scanner 3D data product of a calibration test frame deployed in Tampa Bay.

3 WORK COMPLETED

The characterization and integration of the BlueView 3DSLS “line sonar”, as well as the acceptance testing of the Bluefin 12.75” diameter AUV, was done based on the following statement of work:

- Continue investigation of leading-edge technology that may be suitable for the MIP.
  - We have pursued the development of a 2.25 MHz 3DSLS with BlueView technologies. This has the potential to replace our current Laser Line Scanner (LLS), i.e. using the 3DSLS would provide resolution similar to the LLS, would not be limited by clarity of the water, and would yield extremely high resolution 3D data products in black or zero visibility waters often found in coastal and port environments.
  - We investigated the use of the BlueView 3DSLS (1.35 MHz) sonar for supporting automated target detection.

- Take delivery of Bluefin B12 AUV tail section (Figures 3 and 4).
  - We have completed the Factory Acceptance Test (FAT) and have participated in two attempts to complete the Sea Acceptance Trials (SAT). However, due to issues associated with the Bluefin integrated Inertial Navigation System (INS), the AUV was found to be functionally deficient and thus has not been accepted. Bluefin has indicated that the INS integration issues have been resolved and that the AUV SAT should be able to be completed in the November, 2008 timeframe.

- Attend AUV Fest 2007.
  - We attended AUV fest and presented data collected by the MIP 3DSLS sonar and LLS as well as providing a static display of the MIP AUV payload.

- Upgrade the ONR 1.35 MHz 3DSLS with a 90 degree FOV array set.
  - The order has been placed with BlueView, but the 90 degree FOV arrays are not expected to be available until the end of calendar year 2008.

- Integrate 90 degree FOV 3DSLS “line sonar” into the MIP Bluefin B12 payload.
  - We have worked with BlueView to ensure that the mechanical aspects, such as form factor, will work in the 12.75” diameter AUV payload hull. We also addressed communications, power, and software integration issues.

- Test and evaluate the AUV-based MIP by performing baseline sea floor scans and the scanning of the bottom of ship hulls within Tampa Bay and offshore.
  - The current 3DSLS (1.35 MHz, 45 deg FOV) has been tested during both our first attempt to complete the AUV SAT, in Boston, and second attempt to complete the AUV SAT in Tampa Bay. Despite the limited functionality of the B12 AUV, data were successfully collected in both cases. We have also scanned the underside of ship hulls and mine-like targets using our ROV with the AUV-based MIP payload attached (Figures 5, 6, and 7).

- Refine the MIP AUV launch and recovery system for the Bluefin B12 AUV.
  - A safe and reliable launch and recovery method, along with supporting hardware, has been developed and tested for operations off of the USGS Research Vessel Gilbert.

Figure 3. BF12 AUV photos taken during our November/December 2007 acceptance trials in Boston. The MIP payload consisted of the BlueView line sonar 3DSLS (model MB1350), payload interface module (silver bullet), and ultra short baseline USBL tracking beacon.

Figure 4. Recovery of the AUV during November/December 2007 acceptance trials off Boston.

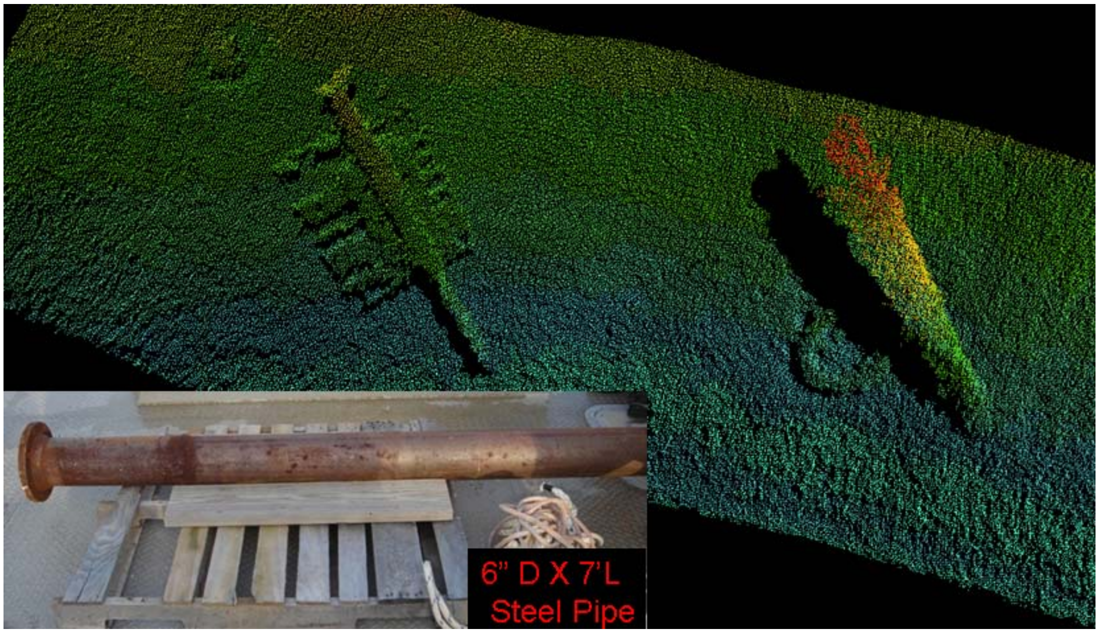

Figure 5. A single scan using the BlueView 3DSLS (1.35 MHz) operated onboard a SeaMax SMX-1000 ROV. The steel pipe is 6" in diameter and 7 feet long. The object on the left side is a partially fallen 13" diameter wooden piling with a tire under it.

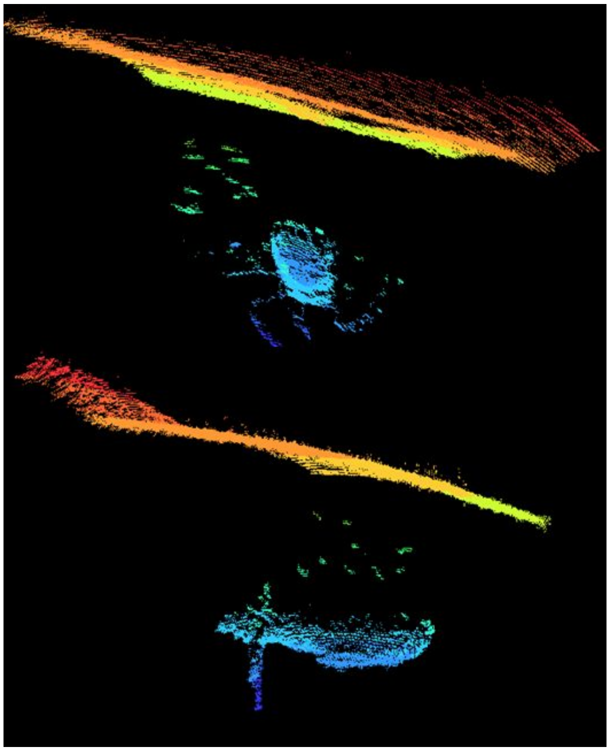

Figure 6. A single scan of a thruster pod suspended from the hull of a vessel docked in the Port of St. Petersburg, Florida. The scanning instrument used is the BlueView 3DSLS (1.35 MHz) operated on the SeaMax SMX-1000 ROV. Above the thruster is a small group of fish (visually verified).

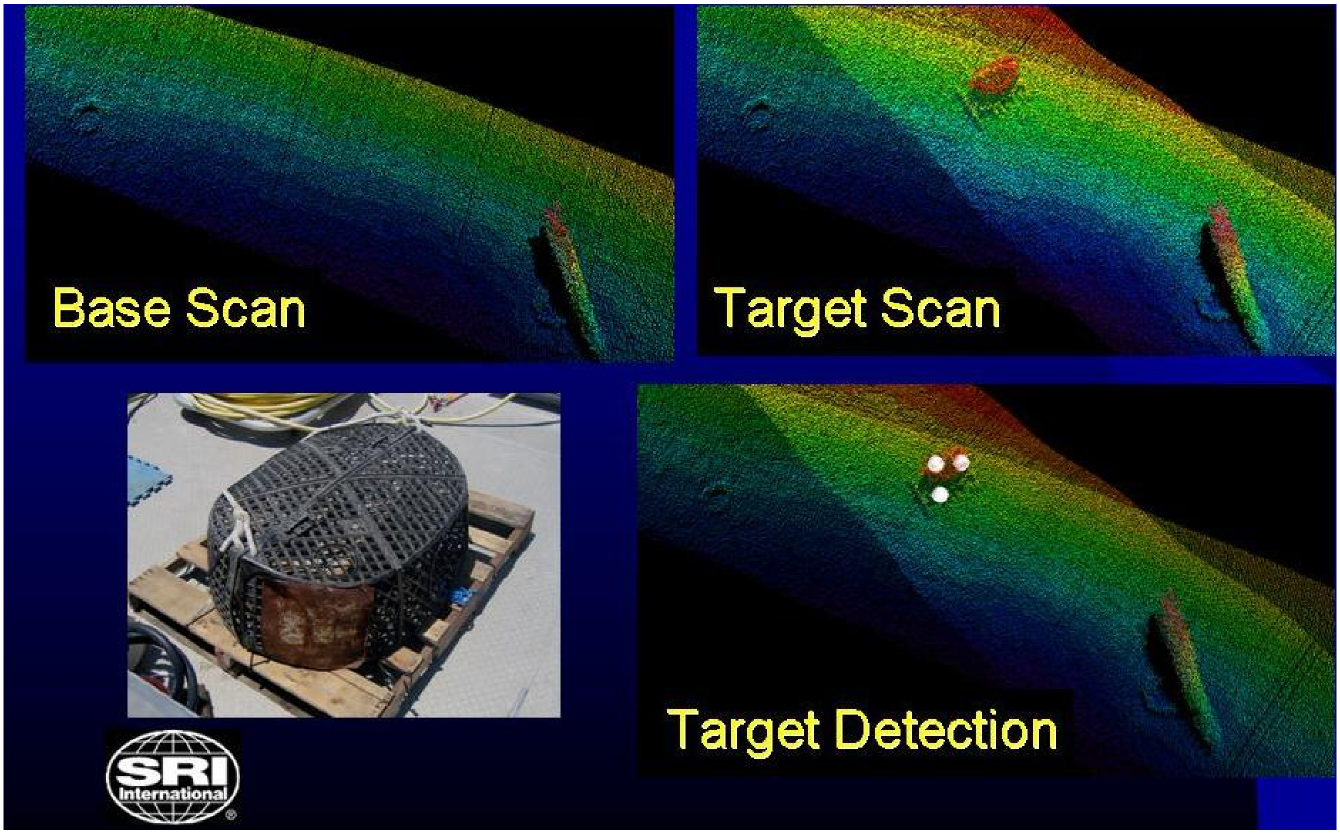

Figure 7. Sonar scans to investigate the feasibility of using the 3DSLS sonar for automated target detection. The 3SDLS sonar was mounted to a small harbor craft with a swing pole to perform a "Base Scan" of the Port of St. Petersburg. Next, a plastic fish trap on a wooden pallet (lower left image) was deployed. Then a "Targeted Scan" of the area was performed. Finally, the base scan and targeted scan data was processed with automated change-detection software. The software detected the new object and placed a white color sphere at that location ("Target Detection").

RESULTS

The testing and development of the AUV-equipped MIP payload has been limited by hardware failures and delays of the Bluefin BF12 tail section. It is hoped that the tentatively scheduled completion of the Sea Acceptance Trials in November will allow for much more through testing and refinement of the MIP-equipped AUV for ship hull scanning.

4 IMPACT AND APPLICATIONS

Future funding for the testing and evaluation of MIP-equipped AUV for ship hull scanning is the next logical step after the reliability of the Bluefin B12 AUV tail section has been proved. A small MIP-equipped AUV would give field personnel the capability to quickly scan ship hulls, both near shore and offshore, with a minimally intrusive platform that can be rapidly deployed on site worldwide. Further, automated detection/classification tools will significantly enhance the utility of such a vehicle.

Previous Related Projects

- **ONR Award N0014-03-1-0750** *Testing and Evaluation of the Mobile Inspection Platform*
- **ONR Award N0014-02-1-0825** *Autonomous Underwater Vehicle for Homeland Defense and Research Support*
- **ONR Award N0014-02-1-0719** *A Autonomous Underwater Vehicle for Homeland Defense*

Acknowledgements

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